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Mathematics Literacy: Are We Able To Put The Mathematics We Learn Into Everyday Use?

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It is common knowledge that most adults have a phobia with mathematics. Was the way mathematics was taught to them a contributing factor to the phobia? How much of the mathematics that we learn in school are we able to use in our everyday life? What constitute mathematics literacy? What is the essence of mathematics literacy? What competencies are required for mathematics literacy? The answers to these questions are the focus of this paper. Mention is made also of the nature of mathematics.

Key words: mathematics literacy, mathematics teaching, nature of mathematics.

Introduction

Mathematics literacy does not imply detailed knowledge of calculus, differential equations, topology, analysis, linear algebra, abstract algebra, and complex sophisticated mathematical formulas, but rather a broad understanding and appreciation of what mathematics is capable of achieving. This paper discusses what mathematics literacy is; the essence of mathematics literacy; and the nature of mathematics. It also discusses what constitutes mathematics literacy and lists the competencies needed to attain mathematics literacy. It is important to note that the mathematics we study and the mathematics we need to know are two different things. The need to make this distinction rests with the fact that not every contents of mathematics we have been exposed to as students can be applied in our daily lives as adults. The author sees an issue with many adults not being mathematically literate and presents a couple of actual scenarios that depict mathematics illiteracy. This conversation has become necessary because mathematics illiteracy that has registered deep in society affects all of us. According to Posamentier and Jaye (2006), “Mathematical deficiency seems to be common in our society and the mathematics illiteracy is particularly alarming, especially in the context of our country’s poor showing on recent international comparison tests” (p. 44).

Mathematics Literacy Defined

Put simply, mathematics literacy is the knowledge to know and apply basic mathematics in our every day living. However, various authors have put an academic spin on what mathematics literacy is. For example, The Organization for Economic Corporation and Development (OECD, 1999) defined mathematics literacy as “an individual capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments, and to engage in mathematics in ways that meet the needs of that individual’s current and future life as a constructive, concerned and reflective citizen." Another meaning developed by The National Adult Literacy Study, a project mandated by congress and carried out by the Educational Testing Service (ETS) in 1995, is that literacy involves "using printed and written information to function in society, to achieve one's goals and to develop one's potential." The study used three scales to quantify adult literacy: Pros Literacy, Document Literacy and Quantitative Literacy (mathematics literacy). *Pro Literacy* includes the knowledge and skills to understand and use information in continuous texts such as editorial and news stories. *Document Literacy* describes the skills and knowledge needed to locate and use information contained in a variety of document formats – maps, schedules, payroll slips, entry forms, etc. *Quantitative Literacy* refers to the skills and knowledge required to apply mathematical operations (arithmetic) to numbers embedded in printed formats. For example, completing an order form or balancing a checkbook are typical tasks requiring quantitative literacy.

The study's concept of adult literacy was heavily based on the use of mathematics and emphasized the practical skills of everyday life. Some examples from the study tested mathematics knowledge that ranged from Level I questions like "Total a bank deposit entry" to Level 5 questions like "Use information in a news article to calculate the difference in time for completing a race." Of all the adults tested, 21% were found to be in the lowest level of pros literacy and 3% in the highest. The corresponding figures for documentary literacy were 23% and 3%. For quantitative literacy (mathematics literacy), the figures were 22% and 4%. Based on these figures, one can infer that illiteracy in mathematics and other kinds of illiteracies are quite high. The reader is encouraged to read the entire report and see for themselves the magnitude of adult illiteracy in mathematics.

An alternative conception of literacy, one that for other purposes may be more useful, is to characterize literacy in terms of the minimum knowledge and skill an individual would need to be considered literate in any given domain. While the definition of adult literacy in the ETS report speaks of "knowledge that is needed," the knowledge that counts is clearly process knowledge rather than content knowledge- knowledge of how to do something rather knowledge of something. For example, an adult might know that calculating the Simple Interest of a deposited sum of money in a bank is: Principal x Time x Rate / 100. But to actually crunch the numbers and arrive at an accurate answer requires another kind of knowledge and skill.

The Essence of Mathematics Literacy

Mathematical literacy involves more that executing procedures. It implies a knowledge base and the competence and confidence to apply this knowledge in the practical world. A mathematically literate person can estimate, interpret data, solve day-to-day problems, reason in numerical, graphical, and geometric situations, and communicate using mathematics. As knowledge expands and the economy evolves, more people are working with technologies or working in settings where mathematics is a cornerstone. Problem solving, the processing of information, and communication are becoming routine job requirements. Mathematics literacy is necessary both at work and in daily life. It is one of the keys to coping with a changing society. Mathematics literacy is as important as proficiency in reading and writing.

Mathematics is so entwined with today's way of life that we cannot fully comprehend the information that surrounds us without a basic understanding of mathematical ideas. Confidence and competence in mathematics leads to productive participation in today's complex information society and often opens doors of opportunities to those who possess them. Mathematics illiteracy, which is the inability to handle numbers and data correctly and to evaluate statements regarding problems and situations that invite mental processing and estimating, is a greater problem than our society recognizes. According to Treffers (1991), this level of innumeracy might not be the result of content taught (or not taught) in schools but rather the result, at least in part, of the structural design of the teaching practices. Two examples of mathematics illiteracy are highlighted below:

In 1990, a newspaper reported (Amsterdam Post, 1990, p. 8):

> Yesterday, Monday October 9, AVRO Television paid attention to analphabetism in The Netherlands. From data collected for the transmission, it appeared that no fewer than 1 out of 25 people cannot read or write. That is, cannot read or write a shopping list, cannot follow subtitles on TV, cannot read a newspaper, cannot write a letter. Just imagine, 1 out of 25 people, in a country that sends helpers to developing countries in orders to teach their folks reading and writing! 1 out of 25, which means 25% of our citizens. How many citizens does The Netherlands have? 14 million? That means that in our highly developed country no less than three and a half million cannot read and write.

Obviously, the TV reporter, directors, and producers that worked on this news item lacked a conceptual understanding of percents. More troubling is the fact that these people are presumed to have been educated. Suffice to say that being literate (that is the ability to read and write) does not guarantee mathematics literacy or numeracy. Mathematics errors such as the one highlighted above are often noticed on a daily basis in society.

Here is another scenario taken from Posamentier and Jaye (2006):

> A recent visit to a picture-framing shop highlighted a mathematical deficiency that seems to be common in our society. An inspection of the bill for framing two pictures, one four inches by twenty inches, and the other twelve inches by twelve inches revealed that they cost the same. When questioned, the proprietor responded that the same amount of framing was used for the two pictures, and that the glass was figured on the basis of "united inches." He was immediately asked what this unit of measurement meant. He indicated that it was the sum of the length and the width; in this case each had twenty-four united inches, and the cost was the same for the two pieces of glass. The merchant was asked if he believed the two frames required the same amount of glass. He wasn't sure, assumed they did, since the two had the same number of united inches. A math teacher listening to this discussion chimed in to give him a quick lesson on rectangle area. The proprietor was amazed to discover that he had been charging the same amount for the two pieces of glass, when, in fact one's area (144sq. in.) was almost twice that of the other (80 sq. in.). This mathematical illiteracy is particularly alarming… (p. 179).

These manifestations of mathematics illiteracy are prevalent in society. One way to account for the problem is that either the content of mathematics learned in school is not making citizens mathematically literate or the methods of teaching the concepts are not helping citizens make connections to real-life situations.

An important part of mathematics literacy is using, doing, and recognizing mathematics in a variety of situations. In dealing with issues that lend themselves to a mathematical treatment, the choice of mathematical methods and representations often depends on the situations in which the problems are presented. Teachers of mathematics often complain that students have difficulty applying the mathematics they have learned in different contexts. As Hughes-Hallett (2001) correctly observed, nonscience students dislike contexts involving physics applications in mathematics because they do not understand the physics. Building from this, it is expedient to examine the wisdom of confronting nonscience students with mathematics applications that need specific science literacy at a nonverbal level. To effectively transfer their knowledge from one area of application to another, students need experience solving problems in many different situations and contexts (De Lange, 1987). Making competences a central emphasis facilitates this process: competencies are independent of the area of application. Students should be offered real-world situations relevant to them, either real-world situations that help them function as informed and intelligent citizens or real-world situations that are relevant to their areas of interest, either professionally or educationally.

Steen (2001) itemized an impressive list of expressions of numeracy which he placed in 4 categories of personal life, school life, work and leisure, and the local community. Under *personal life* we include, depending on age, games, daily scheduling, sports, shopping, saving, interpersonal relations, finances, voting, reading maps, reading tables, health, insurance, and so on. *School life* relates to understanding the role of mathematics in society, school events (e.g., sports, teams, scheduling), and understanding data, computers, and so on. *Work and leisure* involves reasoning, understanding data and statistics, finances, taxes, risks, rates, samples, scheduling, geometric patterns, two- and three-dimensional representations, budgets, visualizations, and so on. In the *local community*, we see intelligent citizens making appropriate judgments, making decisions, evaluating conclusions, gathering data and making inferences, and in general, adopting a critical attitude – seeing the reasoning behind decisions.

The Nature of Mathematics

In order to better understand mathematics literacy, it is important to throw some light on the subject matter of mathematics. Mathematical concepts, structures, and ideas have been invented as tools to organize phenomenon in the natural, social, and mental worlds. In the real world, the phenomena that lend themselves to mathematical treatment do not come organized as they are in school curriculum structures. Rarely do real-life problems arise in ways and contexts that allow their understanding and solutions to be achieved through an application of knowledge from a single content strand. If we look at mathematics as a science that helps us solve problem, it makes sense to use a phenomenological approach to describe mathematical concepts, structures, and ideas. This approach has been followed by Freudenthal (1973) and by others such as Steen (1990), who stated that if mathematics curricula featured multiple parallel strands, each grounded in appropriate childhood experiences, the collective effect would be to develop among children diverse mathematical insight into the many different roots of mathematics. Steen then suggested that we should seek inspiration in the developmental power of five deep mathematical ideas: dimensions, quantity, uncertainty, shape, and change. The Program for International Student Assessment (PISA) under OECD has mathematics expert groups that adapted these ideas, creating four phenomenological categories to describe what constitutes mathematics: quantity; space and shape; change and relationship; and uncertainty. These are discussed below.

Quantity

This overarching idea focuses on the need for quantification to organize the world. Important aspects include an understanding of relative size, recognition of numeral patterns, and the ability to use numbers to represent quantifiable attributes of real-world objects (measures). Furthermore, quantity deals with the processing and understanding of numbers that are represented to us in various ways. An important aspect of dealing with quantity is quantity reasoning, whose essential components are developing and using number sense, representing numbers in various ways, understanding the meaning of operations, having a feel for the magnitude of numbers, writing and understanding mathematically elegant computations, doing mental arithmetic, and estimating.

Space and Shape

Patterns are encountered everywhere around us: in spoken words, music, video, traffic, architecture, art, etc. Shapes can be regarded as patterns: houses, office buildings, bridges, snowflakes, town plans, crystals, shadows, etc. Geometric patterns can serve as relative simple models of many kinds of phenomena, and their study is desirable at all levels (Grunbaum, 1985). In the study of shapes and constructions, we look for similarities and differences as we analyze the components of form and recognize shapes in different representations and dimensions. The study of shapes is closely connected to the concept of "grasping space" (Freundenthal, 1973) - learning to know, explore, and conquer, in order to live, breathe, and move with more understanding in the space in which we live. To achieve this, we must be able to understand the properties of objects and their relative positions; we must be aware of how we seek things and why we see them as we do; and we must learn to navigate through space and through constructions and shapes. This requires understanding the relationship between shapes and images (or visual representations) such as that between a real city and photographs and maps of the same city. It also includes understanding how three-dimensional objects can be represented in two dimensions, how shadows are formed and interpreted, and what perspective is and how it functions.

Change and Relationship

Every natural phenomenon is a manifestation of change, and in the world around us a multitude of temporary and permanent relationships among which phenomena are observed: organisms changing as they grow, the cycle of seasons, cycles of unemployment, weather changes, stock market fluctuations. Some of these change processes can be modeled by straightforward mathematical functions: linear, exponential, periodic or logistic, discrete or continuous. But many relationships fall into different categories, and data analysis is often essential to determine the kind of relationship present. Mathematical relationships often take the shape of equations or inequalities, but relations of a more general nature (e.g., equivalence, divisibility) may appear as well. Functional thinking – that is, thinking in terms of and about relationships- is one of the fundamental aims of teaching mathematics. Relationships can take a variety of different representations, including symbolic, algebraic, graphic, tabular, and geometric. As a result, translation between representations is often of key importance in dealing with mathematical situations.

Uncertainty

Our information driven society offers an abundance of data, often presented as accurate and scientific and with a degree of certainty. But in daily life we are confronted with uncertain election results, collapsing bridges, stock market crashes, unreliable weather forecasts, poor prediction of population growth, economic models that do not align, and many other demonstrations of the uncertainty of our world. Uncertainty is intended to suggest two related topics: data and chance, the phenomenon that is a subject of mathematical study in statistics and probability, respectively. Recent recommendations concerning school curricula are unanimous in suggesting that statistics and probability should occupy a much more prominent place than they have in the past (NCTM, 2000). Specific mathematical concepts and activities that are important in this area include collecting data, data analysis, data display and visualization, probability, and inference.

What Constitutes Mathematics Literacy?

Having discussed the nature of mathematics, we now turn attention to the elements that constitute mathematics literacy. Like the many definitions and meanings that have been attached to mathematics literacy, the same phenomenon comes to play when determining what should constitute mathematics literacy. For some, having basic knowledge of number sense and algebra is enough to be mathematically literate. For others, having minimum skills in arithmetic, measurement, algebra, geometry, probability, statistic, and logic is enough to qualify as a mathematically literate person. Still for others, it is the ability to use the knowledge of basic math to solve real-life problems that is necessary. The Organization for Economic Corporation and Development (OECD) publication *Measuring Student Knowledge and Skills* (OECD, 1999) represents as part of reading literacy a list of types of texts, the understanding of which in part determines what constitutes mathematics literacy. The list comes close, in the narrow sense, to describing many aspects of mathematics literacy. The publication mentions, as examples, texts in various formats:

- Forms: tax forms, immigration forms, visa forms, application forms, questionnaires
- Information sheets: timetables, pricelists, catalogues, programs
- Vouchers: tickets, involves, etc
- Certificates: diplomas, contracts, etc
- Call and advertisement

- Charts and graphs; iconic representation of data
- Diagrams
- Tables and matrices

The question then is: How much mathematics should an individual know to be mathematically literate? The following is a suggested list of mathematics skills that an individual should have to be considered literate. This is not an exhaustive list as knowledge is dynamic and technological advancement is ever changing.

In arithmetic, every one should be able to perform the basic operations of addition, subtraction, multiplication, and division in whole numbers, fractions and decimals. They should also know concepts such as roots, square roots, ratios, percents, absolute values, reciprocals, and exponents. In measurement, citizens should know both traditional and metric measures of length, area, volume, weight (or mass), time, and temperature. They should also know how to convert between these measures. In algebra, functional and useful topics can include simple linear equations, plotting graphs of linear equations, slopes, operations in positive and negative integers, and the concept of proportional reasoning. In geometry, citizens should know the various area and circumference formulas for circles, squares, rectangles, and triangles. They should be familiar with the Cartesian coordinate system in two and three dimensions. They should be able to convert size on a scale model or map to actual dimensional size. They should be able to do basic constructions using a compass and straight edge. Citizens should be familiar with three dimensional shapes in terms of finding the volumes and surface areas of shapes like the cone, pyramid, prism, cylinder, and sphere. In statistics, they should be able to find the measure of central tendencies when given a set of values. They should be able to graph data as a histogram, pie chart, bar graph, and line graph. In probability, they should know probabilities based on theory and probability based on experiment, compare risk factors of a given situation; calculate the basic probability of outcomes using the multiplication principle, permutations, or combinations.

The fact of the matter is that not many citizens can boast of a thorough grasp of the skills and concepts highlighted above. As pointed out Posamentier & Jaye (2006), there is a nonchalant attitude of adults towards mathematics as they want to know the relevance of knowing how to do the mathematics when in fact every calculation can be done with the assistance of a calculator or a computer. Do we just stop teaching mathematics for this reason? This is a question that the reader should ponder.

Competencies Needed for Mathematics Literacy

The competencies needed for mathematics literacy are described in the work of Program for International Students Assessment (PISA) under the auspices of OECD and are in line with description by Steen (2001):

- *Mathematics Thinking and Reasoning:* Posing questions characteristic of mathematics; knowing the kind of answers that mathematics offers; distinguishing among different kinds of statements; understanding and handling the extent and limits of mathematical concepts.
- *Mathematical Argumentation:* Knowing what proofs are; knowing how proofs differ from other forms of mathematical reasoning; following and assessing

chains of arguments; having a feel for heuristics; creating and expressing mathematical arguments.

- *Mathematical Communication:* Expressing oneself in a variety of ways in oral, written, and other visual form; understanding someone else's work.
- *Modeling:* Structuring the field to be modeled; translating reality into mathematical structures; interpreting mathematical models in terms of context or reality; working with models; validating models; reflecting, analyzing, and offering critiques of models or solutions; reflecting on the modeling process.
- *Problem Posing and Solving:* Posing, formulating, defining, and solving problems in a variety of ways.
- *Representation:* Decoding, encoding, translating, distinguishing between, and interpreting different forms of representations of mathematical objects and situations as well as understanding the relationship among different representations.
- *Symbols:* Using symbolic, formal, and technical language and operations.
- *Tools and Technology:* Using aids and tools, including technology when appropriate.

To be mathematically literate, individuals need all these competencies to varying degrees, but they also need confidence in their own ability to use mathematics and comfort with quantitative ideas. An appropriation of mathematics from historical, philosophical, and societal points of view is also desirable.

Conclusion

The paper has discussed the issue of mathematics literacy in the light of what mathematical literacy is and the essence of mathematics literacy. It also discusses the nature of mathematics, perspective of what constitutes mathematics literacy, and the competencies that people need to acquire mathematical literacy. The central issue presented here is that our schools have failed to produce mathematically literate citizens that can function well with quantitative acumen. It is true that many factors account for this situation: home, school, parents, society in general, to name a few. It should be noted that everyone is capable of being mathematically literate. The path towards this social goal begins at home and the classroom, supported by the family and community. The way instruction is presented can influence the capability of children in mathematics. Teachers should teach in such a way that conceptual understanding is gained by students. This is the only way they will be capable of applying learned mathematics in real-life as adults. Also, content taught in school mathematics should reflect relevance to society. That way, the ever existing question of where learned material in mathematics will be used in real-life is eliminated.

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